The PHENIX Multiplicity and Vertex Detector

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We describe the design and expected performance of the PHENIX Multiplicity and Vertex Detector (MVD), part of the PHENIX detector at the Relativistic Heavy Ion Collider (RHIC).

1. Introduction

The physics philosophy of the PHENIX experiment is to detect and systematically study the Quark-Gluon Plasma (QGP) via a simultaneous measurement of many different probes/signatures of the plasma, as a function of the energy density achieved in the nucleus-nucleus collision. In order to achieve this goal, PHENIX is designed as a multipurpose spectrometer, comprising two tracking arms in the central rapidity region, two muon detection arms in the forward rapidity regions and detectors for global characterization of the collision arrayed along the beamline. With these detector systems, PHENIX is capable of concurrently measuring hadrons, leptons and photons, as well as global properties of the collision. The PHENIX experiment and physics program are described in more detail in [1–3]; individual detector systems are described in contributions by P. Nilsson and M. Rosati in these proceedings.

At the center of the PHENIX detector is the Multiplicity and Vertex Detector (MVD). The MVD performs several functions within PHENIX, providing a fast measurement of the total charged particle multiplicity over a large kinematic range for a centrality trigger, and allowing a precise determination of the interaction vertex position. Additionally, the MVD is capable of measuring charged particle multiplicity distributions ($dN_{ch}/d\eta d\phi$) over a large range in η and the full azimuthal angle, allowing a systematic investigation of one of the most fundamental physics observables in heavy ion collisions.

2. The Detector

A schematic design of the MVD is shown in Fig. 1. The detector system incorporates a clamshell design, which encloses the beam pipe. There are two hexagonal barrels of Si microstrip detectors, at ~5 cm and ~7.5 cm from the center of the beam pipe. The inner barrel is fully populated, comprising a total of 72 Si detectors, separated into a segmentation of 6 azimuthally and 12 along the beam direction; for the outer barrel, only 2 of the 6 azimuthal sections are fully populated, with the central portion of the other 4 azimuthal sections left empty to reduce the mass of the detector in the acceptance of the central arms. Altogether, there are 112 Si strip detectors, each of which contains 256

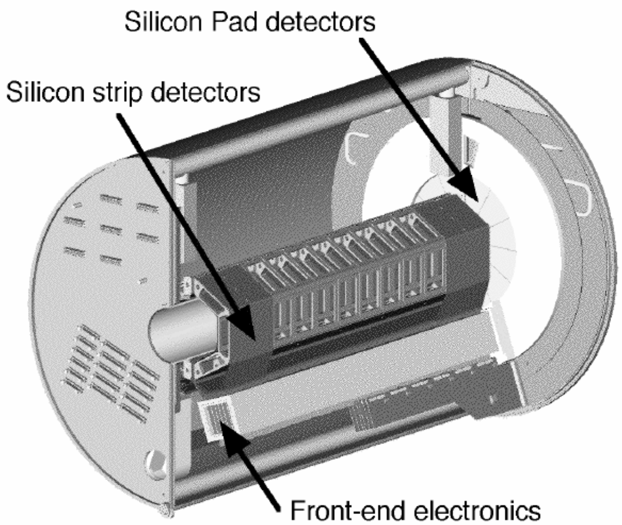

Figure 1. Cutaway diagram of the PHENIX Multiplicity and Vertex Detector. The active area includes two concentric barrels of Si microstrip detectors and two endcaps containing Si pad detectors.

microstrips at a 200 μm pitch, oriented perpendicularly to the beam. The endcaps of the detector each contain 12 Si pad detectors, spanning the radial distance from $\sim$5 to $\sim$12 cm from the center of the beam pipe. Each of these detectors contains 252 square Si pads, which range in area from 4 mm^2 to $\sim$20 mm^2; the dimensions were chosen so that each pad covers $\Delta\eta$=0.04 and $\Delta\varphi$ $\sim$2.5°. All told, the MVD contains just under 35,000 channels. The MVD has excellent acceptance, with the strip detectors covering -2.5 $\leq \eta \leq$ 2.5 and the pad detectors covering 1.8 $\leq |\eta| \leq$ 2.65 for interactions at the center of the MVD (the exact η range depends on the vertex position), and spanning the full range in azimuth.

The primary challenge for the design of the MVD was to produce a compact, low mass detector without sacrificing performance for vertex position resolution and measurement of $dN_{ch}/d\eta$. By using lightweight Rohacell material for the construction, the entire detector was kept to an average of $\sim$1.1% of a radiation length for produced particles, which has kept electron background from γ conversions to manageable levels. Since performance issues require the front-end electronics to be located near the detectors, these components must also be compact and lightweight. To this end, the MVD will utilize a Multi-Chip Module (MCM) fabricated with high-density interconnect (HDI) technology. Each MCM does readout for 256 channels of Si, performing preamplification, storage of signals in a 64 cell analog memory, and digitization for each channel, as well as containing the XILINX FPGA's to manage these processes, and producing an analog sum indicating the total number of channels over threshold for trigger purposes. By utilizing HDI, the MCM houses all of this functionality in a package only 4.8 by 4.3 cm. A production assembly of a Si strip detector connected to an MCM via a custom kapton cable is shown in Figure 2.

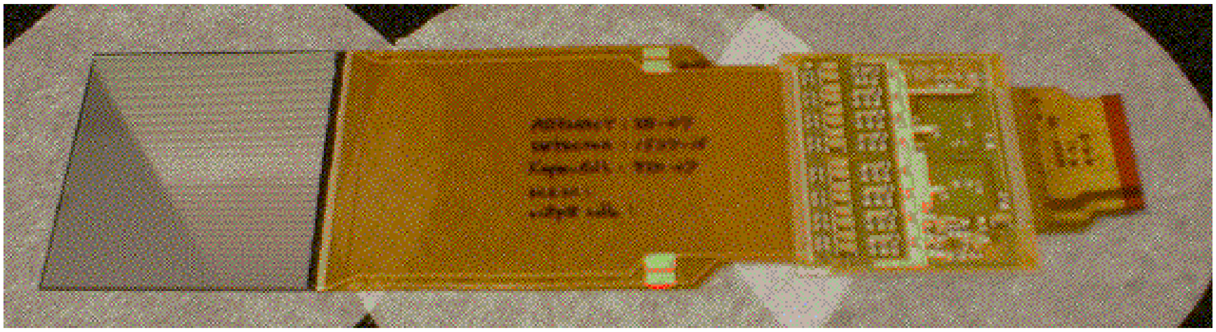

Figure 2. Production assembly of (from left to right) a Si strip detector from the inner barrel, a custom kapton cable, an MCM and its kapton output cable.

One of the primary functions of the MVD is to reconstruct the position of the primary interaction. The high segmentation of the strip detectors allows for a precise determination, with simulated three-dimensional position resolution of better than 200 μm in each dimension. Two algorithms are utilized for reconstructing the vertex position–one relies on projecting all combinations of hits in the outer and inner barrels to the beam line, with a peak indicating the vertex position (transverse dimensions are determined iteratively); the second algorithm takes advantage of the fact that the spatial pattern of energy deposition in the outer and inner barrels are related by the ratio of the barrel radii with a longitudinal offset proportional to the vertex position. Of these algorithms, the first is used except in cases of very high occupancy, where the latter algorithm is more reliable. However, the high segmentation of the strip detectors keeps the expected occupancy levels at a reasonable level; for central Au+Au HIJING events (midrapidity $dN_{ch}/d\eta$ ~800), the occupancy is approximately 50% in the strip detector barrels, and 10-15% for the pad detectors. It should be noted that some models predict multiplicities considerably higher than HIJING. With this in mind, the MVD electronics are designed such that ADC dynamic range should accommodate up to ~6-8 minimum bias particles (MIP) in each strip. Thus, the MVD should be able to make a reasonable $dN_{ch}/d\eta$ measurement at multiplicities considerably higher than predicted values, although certainly things become more complicated as the occupancy becomes very high.

The MVD is also capable of measuring charged particle distributions, $dN_{ch}/d\eta d\phi$, a quantity of fundamental importance in understanding the dynamics of the heavy ion collision. In order to calculate multiplicity, first the gain-corrected strip or pad ADC values are geometrically corrected for path length in the Si (after the vertex has been reconstructed). These values are then summed over some chosen grouping of strips or pads ("clumps"), and normalized to the average MIP energy deposition to get the number of hits. The clump size can be varied, so that this algorithm lends itself nicely to scale-dependent analyses, *e.g.* intermittency or wavelet analyses. In addition, as described in [3], a more sophisticated algorithm exists for determining the multiplicity in the pad detectors, utilizing Poisson statistics and the average occupancy to determine a weighted expectation value for the number of hits in each pad. The response of the MVD to

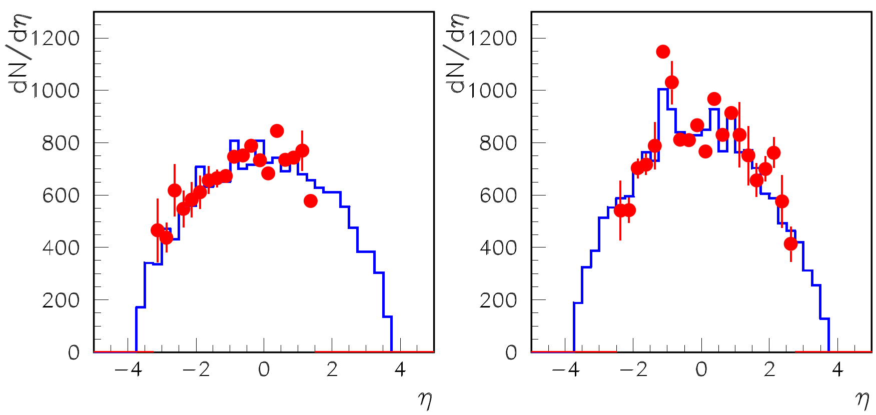

Figure 3. A comparison of $dN_{ch}/d\eta$ distributions from single HIJING Au+Au central events (shown as histograms) to the expected response of the MVD (shown as symbols), from two sample events (see text for details).

HIJING and HIJET events has been simulated, including effects of background particles from interactions in detector material, as well as crosstalk and electronic noise, estimated from prototype tests. Averaged over 125 central Au+Au HIJET events, the mean $dN_{ch}/d\eta$ from the MVD simulation (using bins of $\Delta\eta$=0.25) was within a few percent of the actual input mean $dN_{ch}/d\eta$. Shown in Figure 3 are simulations of MVD reconstruction of single HIJING events. The reconstructed values are very close to the actual input from the model, including events with interaction vertices longitudinally offset from the center of the detector, as shown in the left panel of the figure. The event in the right panel was chosen because it contained a localized multiplicity fluctuation from the event generator, which the MVD has reconstructed quite well. Sensitivity to localized fluctuations is one of the goals of the MVD, because it allows for the study of interesting physics processes which may generate these fluctuations, *e.g.*disoriented chiral condensates.

3. Acknowledgements

As a final note, we would like to recognize the students and postdocs who have made critical contributions to the design and construction of the MVD: Toshiyuki Shiina, University of Alabama-Huntsville; David Jaffe and Eric Bosze, University of California-Riverside; Sang Yeol Kim, Young-Gook Kim and SansSu Ryu, Yonsei University; Rachel Cunningham and Richard Conway, MIT.

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